IJECA
International Journal of
Education & Curriculum Application
http://journal.ummat.ac.id/index.php/IJECA
ISSN 2614-3380 | Vol. 5, No. 3, December 2022

Identification and Analysis of Students' Misconceptions Using Three-Tier Multiple Choice Diagnostic Instruments on Thermochemistry Topic

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Keywords:

Misconception;
Thermochemistry;
Three-Tier Multiple Choice

ABSTRACT

Misconceptions can prevent students from mastering the material more deeply. This is because misconceptions can hinder the process of receiving and integrating knowledge. Therefore, the teacher must identify the misconceptions that occur in students. This study was conducted to identify misconceptions about thermochemistry using a three-tier diagnostic test for students at senior high school with a total of 33 students. The research design used is descriptive research. The research subjects were determined by purposive sampling technique. Data collection used was three-tier multiple choice diagnostic test and interview. Data was analyzed using descriptive statistics with percentages and criteria for misconceptions. The results showed that 16.72% of students understood the content, 36.36% had misconceptions, guessed 18.54% and 28.27% did not understand the concept. Through this finding, in the hope is that teachers could analyze the causes of students' misconceptions, and find appropriate learning methods and media to reduce misconceptions occurred.

Article History:
Received: 25-10-2022
Revised : 05-12-2022
Accepted: 15-12-2022
Online : 15-12-2022

https://doi.org/10.31764/ijeca.v5i3.11613

A. INTRODUCTION

Chemistry is one of the science branches that is difficult for students to understand compared to other branches of science (Chang, R. and Overby, 2011). Difficulties in understanding chemistry are caused by the characteristics of concepts in chemistry which are abstract and difficult (Stojanovska et al., 2017). The abstractness and difficulty of concepts require students to have good conceptual understanding. It is due to if chemical concepts are not well understood, students will have learning difficulties. In the classroom, students sometimes do not include new concepts being taught, but depending on the context that already exists in students' minds (Rodriguez & Towns, 2021). Thus, the new concept finally stands alone and has no meaning, and is not related to other concepts (Kaltakci-gurel et al., 2017; Sreenivasulu et al., 2013). As a result, it leads to misconceptions due to the inability of students in connecting the knowledge.

Misconceptions can prevent students from mastering the learning material more deeply. This is because misconceptions can hinder the process of receiving and integrating knowledge.

Kirbulut (2014) stated that misconception is students' understanding of a concept, but it is different from scientific concepts. Misconceptions can also be interpreted as an unequal understanding of concepts between students and experts (Loh et al., 2014). For example, Sihaloho et al. (2021) found that 48.05% of the students of senior high school had misconceptions about the buffer solution, while another study conducted by Permatasari et al. (2022) at senior high school Kediri showed the percentage of students' misconceptions ranging from 43,91-62,06 %. Another chemical concept that is considered difficult and has potential misconceptions is thermochemistry (Karpudewan et al., 2015). Thus, this study shows that the chemical material is prone to misconceptions, so it is necessary to identify misconceptions so that the misconceptions experienced by students can be immediately identified and immediately corrected.

Relevant research has been conducted by Ade Monita & Suharto (2016) showing that the three tier multiple choice instrument can identify misconceptions about chemical equilibrium in Banjarmasin High School with moderate misconception results. Another study was conducted by Astuti et al (2016) to identify stoichiometry misconceptions in senior high school with the results that misconceptions occur in all concepts, namely the concept of reaction equations, Ar/Mr, and the concept of moles. As many as 40.46% of students had misconceptions about the concept of the reaction equation, 38.36% of students had misconceptions about the concept of Ar/Mr, and as many as 53.77% of students had misconceptions about the concept of moles.

The misconception is important to be identified and corrected immediately so as not to interfere with the next learning process. Misconception can be identified in several ways including making concept maps, interviews, open-ended tests, and multiple-choice tests. Multiple choice test is a misconception identification method that is often chosen because it is easier to manage, process, and analyze compared to other methods (Tan et al., 2019). Nowadays, multiple-choice tests have developed into multi-tier multiple-choice tests. This multi-tier multiple choice test has several types, including two-tier tests, three-tier tests, and four-tier tests (Yan, 2017).

This three-tier diagnostic test is a diagnostic test composed of three levels of questions. The first level (one-tier) is in the form of ordinary multiple choice, the second level (two-tier) is a choice of reasons, and the third level (three-tier) is an affirmation question about the beliefs of the answers that have been selected at levels one and two (Habiddin & Page, 2019; Halmo et al., n.d.). Meanwhile, the definition of a diagnostic test is a test that aims to identify students' learning difficulties in terms of understanding key concepts on a particular topic (Kanli, 2015; Suwarto, 2013). The benefit of the results of this diagnostic test is to be a reference for teachers to determine effective learning patterns in the future (Milenković et al., 2016).

The result of the preliminary study found that chemistry teachers had not fully implemented learning in accordance with the student-centered as demands of the curriculum. The teachers are still more active than the students, where students only listen to the explanation from the teacher and take notes on the material given. It indicates that students are passive in learning. It is confirmed by the results of the interview, which found that the average score of thermochemistry subject matter is also still low and there have never been identified students' misconceptions so far. Therefore, this study aims to identify students' misconceptions of thermochemistry using a three-tier diagnostic test.

B. METHODS

The research design used is descriptive research. Descriptive research aims to investigate conditions or circumstances whose results are described in a straightforward manner and as they are (Ismail et al., 2015). The subjects in this study were students at senior high school as many as 33 students who had studied thermochemistry. The research flow can be seen in Figure 1.

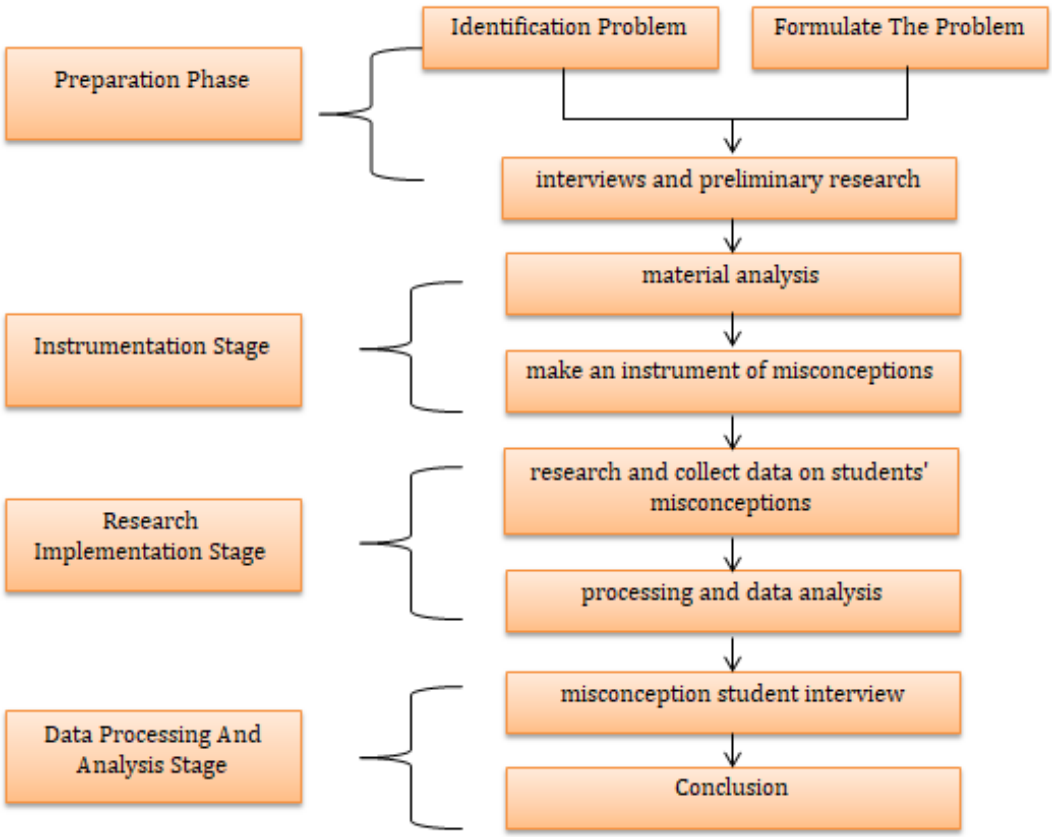

Figure 1. Research Flow (Pesman & Eryilmaz, 2010)

The instrument used in this research is a diagnostic test in the form of a Three-Tier Test with 15 questions that have been developed. Furthermore, to obtain additional information related to the factors causing misconceptions, an interview sheet was used to obtain additional information from teachers and students. All questions are given blank choices to allow students to provide their own answers (Sreenivasulu et al., 2013). The criteria for grouping students' conceptions can be seen in Table 1.

Table 1. Criteria for grouping students' conceptions

Tier 1	Tier 2	Tier 3 (CRI)	Decision
Correct	Correct	Sure	Understand
Correct	Correct	Not Sure	Guess
Correct	Incorrect	Sure	Misconception
Correct	Incorrect	Not Sure	Guess
Incorrect	Incorrect	Sure	Misconception
Incorrect	Incorrect	Not Sure	Don't Understand
Incorrect	Correct	Sure	Misconception
Incorrect	Correct	Not Sure	Guess

The answers given by students are then made in the form of percentages. Calculating the number of samples that have conceptions in the form of percentages based on written test data analysis using the following formula:

$$\%TK = \frac{TK}{N}\ x\ 100\% \quad (1)$$

$$\%TTK = \frac{TTK}{N}\ x\ 100\% \quad (2)$$

$$\%MK = \frac{MK}{N}\ x\ 100\% \quad (3)$$

$$\%MB = \frac{MB}{N}\ x\ 100\% \quad (4)$$

With: TK is group of students who know the concept; TTK is group of students who do not know the concept; MK is group of students who show misconceptions; MB is group of students who guess the answer; N is number of students. Enter the category of level of misconception that students get from the previous percentage calculation according to the category of level of misconception in Table 2.

Table 2. Category Levels of Misconception

Percentage	Category
0 % <Misconception ≤ 30%	Low
30% <Misconception ≤ 70%	Medium
70% <Misconception ≤ 100%	High

(Kurniawan & Suhandi, 2015)

C. RESULT AND DISCUSSION

1. Result

a. Problem Identification

The results of the interview with chemistry teacher of senior high school showed that the student's learning achievement in thermochemistry had not yet reached the minimum completeness criteria set by the school. The average daily test score of students in thermochemistry is 70 while the minimum completeness criteria is 75. The low learning outcomes of students can be caused by several factors, one of which is the error factor in understanding the concept or what is called a misconception.

b. Instrument Making

Before developing the instrument, a syllabus analysis was carried out so that the concepts were not out of concept being taught. After analyzing the syllabus, it was found that there were 4 main concepts of thermochemical material studied, namely, system and environment, exothermic and endothermic reactions, level diagrams and cycle diagrams, and standard enthalpy changes (ΔH°) for various reactions. The concepts are described in form of 15 questions and some of them are adapted from journals, and theses. The adapted questions are changed or modified while still referring to the existing questions.

c. Classification of Educator Conceptions

The data in the study were collected through a diagnostic test using three-level multiple-choice questions consisting of 15 items representing each concept of thermochemistry. Furthermore, based on the test results, students were classified into 4 categories, namely students who knew the concept, misconceptions, guessing and students who did not

know the concept (Brady, 2003). Classification of students' conceptions is done per item. The number of each classification can be seen in Table 3.

Table 3. Conception Classification based on the number of Students

Question Number	Amount per Classification (students)			
	Understand	Misconception	Guess	Don't Understand
1	6	13	8	6
2	11	6	11	5
3	8	13	10	2
4	2	14	10	7
5	12	15	1	5
6	2	12	10	9
7	6	19	1	7
8	2	9	3	19
9	3	2	8	20
10	2	18	3	10
11	4	13	3	13
12	4	9	1	19
13	3	19	3	8
14	3	9	11	10
15	5	10	6	12

d. Percentage of Classification of Students Per Item
After the students are grouped based on their conceptions, then the percentage of each student's conception is calculated per item. The percentage of students' conceptions can be seen in Table 4.

Table 4. Percentage of Students Conceptions per Item Test

Question Number	Percentage per Classification (%)			
	Understand	Misconception	Guess	Don't Understand
1	18,1%	39,3%	24,4%	18,1%
2	33,3%	18,1%	33,3%	15,1%
3	24,2%	39,3%	33,3%	6,06%
4	6,06%	42,4%	33,3%	21,2%
5	36,3%	45,4%	3,33%	15,1%
6	6,06%	36,3%	33,3%	27,2%
7	18,1%	57,5%	3,33%	21,2%
8	6,06%	27,2%	9,09%	57,5%
9	9,09%	6,06%	24,2%	60,6%
10	6,06%	54,5%	9,09%	30,3%
11	12,1%	39,3%	909%	39,3%
12	12,1%	27,2%	3,03%	57,5%
13	9,09%	57,5%	9,09%	24,2%
14	9,09%	27,2%	39,3%	30,3%
15	15,1%	30,3%	18,1%	36,3%

e. Percentage of Classification of Students Per Concept
In addition to identifying misconceptions based on questions, the research results also determine the percentage of students' conceptions per key thermochemical concepts.

For more details, the following is the percentage of student conceptions per concept, as shown in Table 5.

Table 5. Percentage of Students Conceptions of Each Concept

No.	Percentage of Conceptions Per Concept (%)				
	Material Description	**Understand**	**Misconception**	**Guess**	**Don't Understand**
1.	System and environment	27,2%	42,4%	13,6%	16,6%
2.	Exothermic and endothermic	20,4%	37,8%	24,2%	17,4%
3.	Reaction level diagrams and cycle diagrams	10,2%	26,2%	24,2%	39,3%
4.	standard enthalpy change (ΔH°) for various reactions	9,09%	38,8%	12,1%	39,8%

f. Category of Students' Misconception Level

After calculating the percentage of each conception, then proceed with determining the category of the level of students' misconceptions. The category of students' level of misconception can be seen in Table 6.

Table 6. Categories of Students' Misconception Levels

No	Description Material	Misconception Level Category		
		Low	**Medium**	**High**
1.	System and environment		√	
2.	Exothermic and endothermic		√	
3.	Reaction level diagrams and cycle diagrams	√		
4.	Standard enthalpy change (ΔH°) for various reactions		√	

2. Discussion

Problems obtained through interviews and preliminary research indicate that the low learning achievement of students in thermochemical material is caused by students' errors in understanding the concepts of thermochemical material or often called as misconceptions. The occurrence of misconceptions in students is caused by several factors, both those that come from within the students themselves as well as those that come from outside. The following sections are explanations of misconceptions in thermochemistry:

a. Concept of System and Environment

The identification of misconceptions in the system and environment concept used 2 questions, namely question number 1 and 5. Based on the analysis of these questions, it turned out that 42.4% of students experienced misconceptions about the concept of the system and environment. The percentage of students' misconception indicates that the level of misconception on the concept of systems and the environment is moderate. That is because according to the theory proposed by Kurniawan & Suhandi (2015), if students

are in the range of 30% - 70%, it is categorized as moderate level. The details of the misconception can be seen clearly in Table 7.

Table 7. Student's misconceptions in Item Numbers 1 and 5

No.	Misconceptions	Correct concept
1	The system is something that is observed, such as the air around the hydrochloric acid and the magnesium metal. The system is an isolated part so that there is no exchange of energy and matter, namely water solvent. The system is the part that is on the outside that can affect the system, namely hydrochloric acid and magnesium metal. The system is part of the environment that allows the observed reaction to occur, namely a solution of hydrochloric acid	The system is something in the center of attention such as hydrochloric acid and magnesium metal (Brady, 2003).
2	The environment is something that is being observed, namely the beaker. The environment is something that can affect the system in a chemical reaction, namely $PbCl_2$ sediment. The environment is something that is outside the system that is being observed and can affect the system in a chemical reaction, namely a solution of HCl, $Pb(NO_3)_2$ and $PbCl_2$	The environment is something that is outside the system that is being observed and can affect the system, namely the beaker and air (Brady, 2003).

b. Concept of exothermic and endothermic reactions

To identify misconceptions about the concept of exothermic and endothermic reactions, this study used 4 items, namely questions number 2, 3, 6, and 7. The results of this study showed that the percentage of students' misconceptions about the concept of exothermic and endothermic reactions was 37.8%. According to Kurniawan & Suhandi (2015), if students who experience misconceptions in the range of 30% - 70% of students, it can be categorized as a level of misconception on the item is a category of moderate level of misconception. In this case, students experience misunderstandings in interpreting different exothermic and endothermic reactions. The following is an analysis of students' misconceptions in question number 7. Question number 7 aims to identify misconceptions about exothermic and endothermic reactions, in which this question contains equations and pictures of examples of exothermic and endothermic reactions in everyday life. As for examples of misconceptions experienced by students, as shown in Table 8.

Table 8. Student's misconceptions in Item Number 7

Question Number	Students Misconceptions	Correct Concept
7	Rusted iron, Photosynthetic events, Burning wood, Fireworks burning	Burning fuel in motor vehicles (Chang, 2010).

c. Level diagram and cycle diagram

In identifying misconceptions on the concept of level diagrams and cycle diagrams, the questions used are questions number 4, 9 and 15. These questions are questions that identify misconceptions about thermochemical material using level diagrams or cycle

diagrams. From the answers given by students, it turns out that 26.2% of students have misconceptions. Based on the level of misconception by Kurniawan & Suhandi (2015), if students who experience misconceptions are in the range of 0% - 30% of students, it can be categorized that the level of misconception on the item is included in the category of low level of misconception. One of the students' misconceptions on this indicator can be seen in question number 15 as shown in Table 9.

Table 9. Students' misconceptions in Item Number 15

Question Number	Students' Misconceptions	Correct Concept
15	1. Evaporation of water is a process of change of state from the liquid phase to the gas phase $H_2O(l) \rightarrow H_2O(g)$ which undergoes an exothermic reaction, where the heat released is obtained from the enthalpy value of the reactants 2. Evaporation of water is a process of change of state from the liquid phase to the gas phase $H_2O(l) \rightarrow H_2O(g)$ which undergoes an exothermic reaction, where the heat released is obtained from the enthalpy value of the product. 3. Evaporation is the process of changing the state of water from the liquid phase to the gas phase H_2O (l) $\rightarrow$ H_2O (g) which undergoes an endothermic reaction, where the heat absorbed is obtained by reducing the enthalpy of the products by the enthalpy of the reactants divided by 2 moles 4. Evaporation of water is a process of changing state from the liquid phase to the gas phase H_2O (l) $\rightarrow$ H_2O (g) which undergoes an endothermic reaction, where the heat absorbed is obtained from reducing the enthalpy of the products with the enthalpy of the reactants	Evaporation of water is a process of changing state from the liquid phase to the gas phase $H_2O(l) \rightarrow H_2O(g)$ which undergoes an endothermic reaction, where the heat absorbed is obtained by reducing the enthalpy of the products by the enthalpy of the reactants multiplied by 2 moles (Chang, 2010).

d. Concept of Standard Enthalpy Change (ΔH°) For Various Reactions

In identifying misconceptions about the concept of standard enthalpy change (ΔH°) for various reactions, there are 6 questions, namely questions number 8, 10, 11, 12, 13 and 14. In the concept of calculating Kc, the percentage of students' misconceptions about the concept is 38.8%, This shows that the category of students' level of misconception on this concept is a moderate level of misconception Kurniawan & Suhandi (2015). One of the students' misconceptions about this indicator can be seen in Table 10 where the questions identify misconceptions about how to calculate the standard enthalpy change (ΔH°) for various reactions, as seen in Table 10.

Table 10. Students' misconceptions in Item Number 14

Question Number	Students' Misconceptions	Correct Concept
14	a. $C_2H_{2(g)} + 5/2\ O_{2\ (g)} \rightarrow 2\ CO_{2\ (g)} + \ H_2O_{\ (l)}$ ΔH°f reactor =-**Σ**ΔH°f result - ΔH reaction b. $C_2H_{2\ (g)} + 5/2\ O_{2\ (g)} \rightarrow 2\ CO_{2\ (g)} + \ H_2O_{\ (l)}$ ΔH°f reactor =ΔH result + **Σ** ΔH°f result c. $C_2H_{2\ (g)} + 5/2\ O_{2\ (g)} \rightarrow 2\ CO_{2\ (g)} + \ H_2O_{\ (l)}$ ΔH°f reactor = **Σ** ΔH°f result + ΔH reaction d. $C_2H_{2\ (g)} + 5/2\ O_{2\ (g)} \rightarrow 2\ CO_{2\ (g)} + \ H_2O_{\ (l)}$ ΔH°f reactor =+**Σ**ΔH°f result - ΔH reaction	$C_2H_{2\ (g)} + 5/2\ O_{2\ (g)} \rightarrow 2\ CO_{2\ (g)} + \ H_2O_{\ (l)}$ ΔH°f reactor = - **Σ** ΔH°f result + ΔH reaction = 225 kj/mol (Chang, 2010)

Based on the explanation above, it can be categorized that students experience misconceptions on theoretical concepts with a moderate level. This happens because in the learning process, students are more likely to practice doing arithmetic problems than understanding the basic theories and concepts of thermochemical material. This is reinforced by the results of interviews conducted on 33 students at senior high school that the cause of students' misconceptions or errors in understanding thermochemical material is caused by students' mistakes in understanding and constructing thermochemical concepts. The student's explanation was strengthened by obtaining information that the teacher had only used textbooks and the lecture method in teaching the concept of thermochemistry. It is concerning because the concept of thermochemistry should be understood and constructed by students themselves through appropriate learning media that focuses on student-centre learning. When students use a lot of references, they will be able to develop their own knowledge (Adadan & Savasci, 2013; Bain et al., 2018).

D. CONCLUSION AND SUGGESTIONS

Misconceptions occur in every thermochemical concept that is tested on students in Senior High School with a different percentage of misconceptions in each question. It found the average percentage of students who understood thermochemical material was 16.72%, 36.36% of students experiencing misconceptions,18.54% of students guessing, and 28.27% of students didn't understand the concept. Based on the results of students' responses and interviews, it can be concluded that the factors that caused misconceptions in students are students' errors in understanding and constructing thermochemical concepts. Teachers should teach using quality teaching methods and materials so that students understand and have no misconceptions. For further research, it is better to use the latest research instruments and a larger number of questions.

ACKNOWLEDGEMENT

We thank to research and community service institutes and Islamic da'wah who have helped financially with this research.

REFERENCES

Adadan, E., & Savasci, F. (2013). International Journal of Science An analysis of 16 – 17-year-old students ' understanding of solution chemistry concepts using a two-tier diagnostic instrument. *International Journal of Science Education*, *34*(October 2013), 513–544. https://doi.org/10.1080/09500693.2011.636084

Ade Monita, F., & Suharto, D. B. (2016). Identifikasi Dan Analisis Miskonsepsi Siswa

Menggunakan Three-Tier Multiple Choice Diagnostic Instrument Pada Konsep Kesetimbangan Kimia. *Jurnal Inovasi Pendidikan Sains*, *7*(1), 27–38.

Astuti, F., Redjeki, T., & Nurhayati, N. (2016). Identifikasi Miskonsepsi Dan Penyebabnya Pada Siswa Kelas Xi Mia Sma Negeri 1 Sukoharjo Tahun Pelajaran 2015/2016 Pada Materi Pokok Stoikiometri. *Jurnal Pendidikan Kimia Universitas Sebelas Maret*, *5*(2), 10–17.

Bain, K., Rodriguez, J. M. G., & Towns, M. H. (2018). Zero-Order Chemical Kinetics as a Context to Investigate Student Understanding of Catalysts and Half-Life. *Journal of Chemical Education*, *95*(5), 716–725. https://doi.org/10.1021/acs.jchemed.7b00974

Brady, J. E. (2003). *Kimia Universitas Asas dan Struktur Jilid Dua*. Binarupa Aksara.

Chang, R. and Overby, J. (2011). *General Chemistry: The Essential Concept*. Mc Graw Hill.

Chang, R. (2010). *Chemistry 10th edition*. McGraw-Hill.

Habiddin, & Page, E. M. (2019). Development and Validation of a Four-Tier Diagnostic Instrument for Chemical Kinetics (FTDICK). *Indones. J. Chem*, *19*(3), 720–736. https://doi.org/10.22146/ijc.39218

Halmo, S. M., Sensibaugh, C. A., & Lemons, P. P. (n.d.). *Article Student Dif fi culties During Structure – Function Problem Solving S*. 453–463. https://doi.org/10.1002/bmb.21166

Ismail, I. I., Samsudin, A., Suhendi, E., & Kaniawati, I. (2015). *Diagnostik Miskonsepsi Melalui Listrik Dinamis Four Tier Test*. *2015*(Snips), 381–384.

Kaltakci-gurel, D., Eryilmaz, A., & Mcdermott, L. C. (2017). Development and application of a four-tier test to assess pre-service physics teachers ' misconceptions about geometrical optics. *Research in Science & Technological Education*, *5143*(April), 1–23. https://doi.org/10.1080/02635143.2017.1310094

Kanli, U. (2015). *Using a Two- tier Test to Analyse Students ' and Teachers ' Alternative Concepts in Astronomy*. *26*(2), 148–165.

Karpudewan, M., Treagust, D. F., Mocerino, M., Won, M., & A. L. Chandrasegaran. (2015). Investigating High School Students ' Understanding of Chemical Equilibrium Concepts. *International Journal of Environmental & Science Education*, *10*(6), 845–863. https://doi.org/10.12973/ijese.2015.280a

Kirbulut, Z. D. (2014). *Using Three-Tier Diagnostic Test to Asse ss Students ' Misconceptions of States of Matter*. *10*(5), 509–521. https://doi.org/10.12973/eurasia.2014.1128a

Kurniawan, Y., & Suhandi, A. (2015). The Three Tier-Test for Identification The Quantity ofStudents' Misconception on Newton's First Laws. *Prociding GTAR*, 313–319.

Loh, A. S. L., Subramaniam, R., & Tan, K. C. D. (2014). Exploring students' understanding of electrochemical cells using an enhanced two-tier diagnostic instrument. *Research in Science and Technological Education*, *32*(3), 229–250. https://doi.org/10.1080/02635143.2014.916669

Milenković, D. D., Hrin, T. N., Segedinac, M. D., & Horva, S. (2016). Development of a Three-Tier Test as a Valid Diagnostic Tool for Identi fi cation of Misconceptions Related to Carbohydrates. *Journal of Chemical Education*. https://doi.org/10.1021/acs.jchemed.6b00261

Permatasari, M. B., Muchson, M., Hakimah, N., & Rokhim, D. A. (2022). *Identifikasi Miskonsepsi Materi Kesetimbangan Kimia Pada Siswa SMA Menggunakan Tes Three Tier Berbasis Web Jurnal Inovasi Pendidikan Kimia Identifikasi Miskonsepsi Materi Kesetimbangan Kimia Pada Siswa SMA Menggunakan Tes Three Tier Berbasis Web*. *January*. https://doi.org/10.15294/jipk.v16i1.29407

Pesman, H., & Eryilmaz, A. L. I. (2010). Development of a Three-Tier Test. *Journal of Educational Research*, *103*, 208–222. https://doi.org/10.1080/00220670903383002

Rodriguez, J.-M. G., & Towns, M. H. (2021). Research and Practice Analysis of biochemistry students ' graphical reasoning using misconceptions constructivism and fine-grained constructivism : why assumptions matter for research and teaching. *Chemistry Education Research and Practice*. https://doi.org/10.1039/d1rp00041a

Sihaloho, M., Hadis, S. S., Kilo, A. K., & La Kilo, A. (2021). Diagnosa Miskonsepsi Siswa SMA Negeri 1 Telaga Gorontalo pada Materi Termokimia. *Jambura Journal of Educational Chemistry*,

3(1), 7–13. https://doi.org/10.34312/jjec.v3i1.7133

Sreenivasulu, B., Subramaniam, R., & Technological, N. (2013). University Students ' Understanding of University Students ' Understanding of Chemical Thermodynamics. *International Journal of Science Education*, *35*(September 2013), 37–41. https://doi.org/10.1080/09500693.2012.683460

Stojanovska, M., M. Petruševski, V., & Šoptrajanov, B. (2017). Study of the Use of the Three Levels of Thinking and Representation. *Contributions, Section of Natural, Mathematical and Biotechnical Sciences*, *35*(1), 37–46. https://doi.org/10.20903/csnmbs.masa.2014.35.1.52

Suwarto. (2013). *Pengembangan Tes Diagnostik Dalam Pembelajaran*. Pustaka Pelajar.

Tan, K. C. D., Taber, K. S., Liew, Y. Q., & Teo, K. L. A. (2019). Chemistry Education Research and Practice. *Education Research Chemistry and Practice*, 1–45. https://doi.org/10.1039/C8RP00215K

Yan, Y. K. (2017). Research and Practice nature of students ' alternative conceptions on. *Chemistry Education Research and Practice*. https://doi.org/10.1039/C7RP00143F